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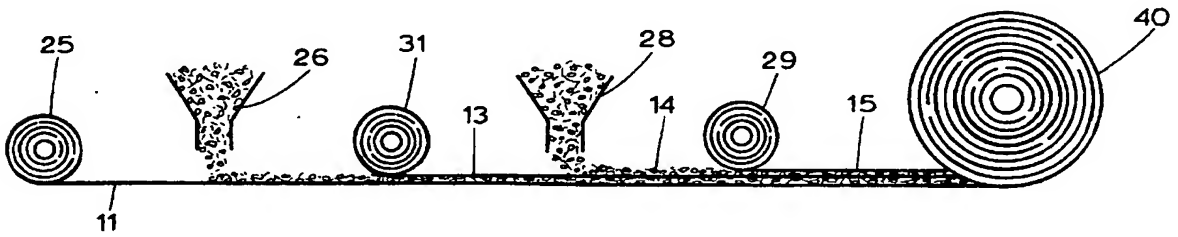
(54) Low permeability geosynthetic clay liner and method of manufacture thereof

(57) A flexible geosynthetic clay liner (10) with a low permeability or controlled permeability intermediate sheet (13) is provided. The liner (10) includes two outer sheets (11,15) with two layers (12,14) of bentonite and an intermediate sheet (13) disposed therebetween. The intermediate sheet (13) may be rippled or deformed to enhance the structural stability of the liner (10). The intermediate sheet (13) may be chosen from a material with low or ultra-low permeability characteristics or may be chosen from a material with controlled or directional permeability characteristics.

FIG. 5



EP 0 742 321 A1

Description

FIELD OF THE INVENTION

This invention relates generally to flexible geosynthetic clay liners for use in creating low permeability bottom layers or barriers in waste containment sites, man-made bodies of water and other applications where a low permeability, flexible barrier is required. More specifically, this invention relates to a geosynthetic clay liner with a low or controlled permeability sheet or layer included within the body of the geosynthetic clay liner. Still more specifically, the present invention relates to a geosynthetic clay liner consisting of two flexible textile sheets with at least one flexible layer of bentonite and a low or controlled permeability flexible sheet or layer disposed therebetween.

BACKGROUND OF THE INVENTION

The concept of using flexible geosynthetic clay liners (GCLs) for creating a low permeability layer or barrier for use in landfills and man-made bodies of water is well known. While flexible GCLs made with bentonite provide an effective barrier, users of such GCLs often complain that the GCLs are not effective enough, i.e. the GCLs do not provide sufficiently low permeabilities under certain circumstances, such as landfill caps and deep ponds, because of low confining stresses that can practically be applied to the GCL as a result of soil cover thickness limitations.

For example, many state regulations and project specifications require that the drainage out of a man-made pond be less than 500 gallons per day per acre of pond. This requirement is problematic for deep ponds where the height of the water level is greater than 3 feet. In practice, the drainage out of deep ponds lined with conventional GCLs generally exceeds several thousand gallons per day per acre of pond because current GCLs have permeabilities ranging from 5×10^{-9} cm/sec to 1×10^{-7} cm/sec. Further, typical GCLs are relatively thin having a typical thickness of 0.7".

Therefore, it would be desirable to provide a bentonite GCL with an improved or controlled permeability. The resulting GCL would be an ultra low permeability GCL used to provide an effective barrier against the transmission of liquids (i.e. with permeabilities less than about 5×10^{-10} cm/sec, preferably less than about 1×10^{-10} cm/sec).

BRIEF DESCRIPTION OF THE INVENTION

The present invention makes a significant contribution to the flexible geosynthetic clay liner art by providing a liner with improved low permeability characteristics and/or controlled permeability characteristics. Specifically, reviewing the construction of the GCL of the present invention from bottom to top, the GCL includes a flexible primary carrier sheet with a first flexible layer of bentonite disposed on top of the primary carrier sheet. A middle or intermediate flexible layer of sheet material or fabric is disposed on top of the first layer of bentonite and an optional second flexible layer of bentonite is disposed on top of the middle or intermediate layer. Finally, a top flexible cover sheet is disposed on top of the second layer of bentonite.

In the alternative, the middle or intermediate flexible layer of sheet material or fabric may be disposed adjacent to the cover sheet or with only a single layer of bentonite disposed between the intermediate layer and the primary carrier sheet. Also, the intermediate layer may be disposed adjacent to the primary carrier sheet with only a single layer of bentonite disposed between the intermediate layer and the cover sheet.

The intermediate flexible layer can provide improved low permeability characteristics and controlled permeability characteristics. Specifically, if the intermediate layer is in the form of a sheet, the intermediate sheet may be fabricated from a flexible sheet of plastic material that will not permit the migration of any substantial amounts of liquid. Alternatively, the intermediate sheet may be fabricated from a flexible plastic sheet that will permit the migration of small, controlled amounts of liquid.

The intermediate layer may also be provided in the form of a flexible coating of polymer over the first bentonite layer. Again, an optional second flexible bentonite layer may be disposed on top of the coating of polymer material.

Further, the low permeability characteristics of the present invention may be enhanced by constructing the GCL with a high swelling, low permeability and/or chemically altered bentonite clay.

The structural stability of the GCL of the present invention may also be enhanced by using an intermediate flexible sheet of a corrugated or wave-like configuration. The intermediate layer may also be altered chemically or mechanically in a way to enhance the adherence of the bentonite to the intermediate layer. If the intermediate layer is in the form of a polymer that is sprayed on or otherwise applied to the first layer of bentonite, the polymer may be chosen so it attains a relatively rigid structure after it dries, while maintaining flexibility to the overall GCL, so it can contribute to the structural stability of the flexible GCL as well.

It will be noted that the bottom flexible sheet that engages the ground is generally known as the primary carrier sheet and that the top sheet on which landfill material is deposited is generally known as the cover sheet. These materials must be flexible to allow the GCL to bend in correspondence to the contours and shapes of the surface that it covers. However, it will also be noted that the primary carrier sheet and cover sheet may be made of identical fabric thereby enabling either the top or bottom sheet to face downward. In any event, this invention is not limited to a specific primary carrier sheet material or any specific top cover sheet material.

The present invention also lends itself to an improved method of manufacturing an improved flexible GCL which comprises the following steps. The first layer of bentonite, in a granular form, powdered form, or mixtures, is disposed on top of either a primary flexible carrier sheet or flexible cover sheet. An intermediate layer of flexible sheet material, in one embodiment, is disposed on top of the first layer of bentonite. An optional second flexible layer of bentonite is disposed on top of the intermediate sheet material layer before either the cover sheet or the primary carrier sheet is disposed on top of the second layer of bentonite to complete the sandwich-type construction of the flexible GCL. Then, the GCL can be held together in a variety of methods including gluing, sewing or needle-punching. Glue can be applied to the inside-facing surfaces of the primary and cover sheets as well as the intermediate sheet or layer during construction. Glue may also be applied to the layers of bentonite.

It is therefore an object of the present invention to provide a flexible GCL with improved low permeability characteristics.

Yet another object of the present invention is to provide a flexible GCL with controlled permeability characteristics.

It is still another object of the present invention to provide an improved method of manufacturing flexible GCLs.

Other objects and advantages of the present invention will become apparent upon reading the following detailed description of the drawings and appended claims, and upon reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention is illustrated more or less diagrammatically in the accompanying drawings wherein:

Figure 1 is a sectional view of a flexible geosynthetic clay liner made in accordance with the present invention;

Figure 2 is a sectional view of another flexible geosynthetic clay liner made in accordance with the present invention;

Figure 3 is a schematic illustration of one method of fabricating a deformed intermediate sheet to be used in flexible geosynthetic clay liners made in accordance with the present invention;

Figure 4 is a schematic illustration of one method of manufacturing a flexible geosynthetic clay liner in accordance with the present invention;

Figure 5 is a schematic illustration of another method of fabricating a flexible geosynthetic clay liner in accordance with the present invention; and

Figure 6 is a schematic illustration of another prefered embodiment of manufacturing the flexible geosynthetic clay liner in accordance with the present invention wherein an intermediate sheet material layer is permanently adhered directly to the primary carrier sheet, e.g., with glue, or pre-adhered as received from a supplier, prior to adding a layer of bentonite clay and then the cover layer.

It should be understood that the drawings are not necessarily to scale and that the embodiments are sometimes illustrated by diagrammatic representations and fragmentary views. In certain instances, details which are not necessary for an understanding of the present invention or which render other details difficult to perceive may have been omitted. It should be understood, of course, that the invention is not necessarily limited to the particular embodiments illustrated herein.

DETAILED DESCRIPTION OF THE DRAWINGS

Like reference numerals will be used to refer to like or similar parts from Figure to Figure in the following description of the drawings.

A sectional view of a flexible GCL made in accordance with the present invention is illustrated in Figure 1. Specifically, the flexible GCL 10 of the present invention includes a flexible primary carrier sheet 11, a first flexible layer 12 of bentonite, in powdered or granular form, preferably in granular form, a flexible intermediate sheet or layer 13, a second flexible layer 14 of bentonite, again preferably in granular form, and a flexible cover sheet 15. Again, it will be noted that the cover sheet 15 and primary carrier sheet 11 may very well be interchangeable. The intermediate layer or sheet 13 as shown in Figure 1 has the ability to dramatically decrease the effective permeability of the GCL 10. In effect, the GCL 10 as shown in Figure 1 can be an ultra low permeability flexible GCL if the flexible intermediate sheet or layer 13 is fabricated from a ultra low permeability material, such as many plastics that are known in the art. The intermediate layer 13 may also be altered chemically or mechanically to enhance the adherence of the bentonite layers 12, 14 to the intermediate layer 13.

The intermediate sheet or layer 13 may be applied in two ways. First, if the intermediate sheet 13 is indeed in sheet form, the sheet maybe simply disposed on top of the first layer of bentonite as shown below in Figure 5. However, if the intermediate layer 13 is a layer of polymer material which is sprayed or otherwise applied in liquid or molten form onto the first bentonite layer 12, the intermediate layer 13 is then applied in accordance with the process shown in Figure 4.

An additional improvement is illustrated by the GCL 20 shown in Figure 2. Again, the GCL 20 includes a carrier sheet 11, a first layer of bentonite 12, a second layer of bentonite 14 and cover sheet 15. However, the GCL 20 includes a flexible rippled or corrugated intermediate sheet or layer 21 which enhances the structural stability of the GCL 20 because the bentonite layers 12, 14 become very slippery when exposed to water. By providing a flexible intermediate sheet or layer, particularly a flexible layer 21, with ripples, corrugations or other

alterations which may be mechanical or chemical in nature, a higher frictional surface may be provided to deter or retard slippage between the bentonite clay layers 12, 14 and the intermediate sheet 21. Chemical or mechanical alterations of the intermediate layer 21 may be used to enhance the adherence of the bentonite layers 12, 14 to the intermediate layers 21. The result is a flexible GCL 20 with the improved permeability characteristics discussed above with respect to the GCL 10 and also with an improved structural stability.

In addition, specific grades or types of bentonite may be selected to enhance the low permeability characteristics of the GCLs 10, 20. A high swelling, low permeability or chemically altered bentonite clay may be selected. One particularly preferable type of clay is western bentonite. The layers of bentonite 12, 14 are applied in amounts approximating one-half pound per square foot but do not have to be applied in equal amounts. Amounts in each layer may vary between zero and 2 pounds per square foot.

Typically, a GCL without an intermediate sheet 13 or 21 will have an overall effective permeability from 1 x 10^{-7} cm/sec to 5 x 10^{-9} cm/sec, depending in the confining stress applied to the GCL. The incorporation of an intermediate sheet or layer such as 13, 21 will provide a flexible GCL with an effective permeability of at least as low as 5 x 10^{-10} cm/sec, preferably a permeability of 1 x 10^{-10} cm/sec or less, and more preferably a permeability of approximately 5 x 10^{-11} cm/sec or less at low confining stresses, thereby providing a substantial improvement.

The intermediate flexible sheets may be fabricated from polyvinylchloride, polyethylene, polypropylene, nylon or other polymeric compounds. Such materials normally weigh between 0.5 to 25 ounces per square yard.

If a controlled permeability is desired, other flexible sheet or fabric materials that offer combinations of controlled or directional permeability may be considered for the intermediate sheets or layers 13, 21. Such materials include battery separator fabrics, fabrics used in disposable diapers and protective clothing.

Figure 3 is an illustration of one method of providing a flexible corrugated or rippled intermediate sheet 21. The sheet 21 is fed between an upper 22 and lower 23 embossing roller to provide the ripple or corrugated effect.

Improved methods of manufacturing low or controlled permeability flexible GCLs 30 and 40 are illustrated in Figures 4 and 5, respectively. Briefly, the flexible carrier sheet 11 is unrolled from the roll 25. The first layer of bentonite 12 is deposited on the carrier 11 as it passes under the hopper 26. The intermediate flexible layer 13 may be applied via one or more spray nozzles or other methods of applying a liquid or molten material shown generally at 27 before the second layer of bentonite 14 is deposited on top of the intermediate layer 13 as the partially-fabricated GCL passes under the hopper 28. Finally, the top flexible carrier 15 is deposited on top of the second layer of bentonite 14 as the GCL passes underneath the roll 29.

The method illustrated in Figure 5 employs the same steps except that the intermediate sheet 13 is provided by the roll 31 as opposed to the nozzles 27 as shown in Figure 4.

In accordance with another preferred embodiment of the present invention, shown in Figure 6, the intermediate flexible sheet material layer 13, preferably a flexible sheet 13 of polymeric material, e.g., a polyolefin, such as polyethylene or polypropylene, is permanently adhered directly to the inner surface of the flexible carrier layer 11, or directly to an inner surface of the flexible cover sheet 15, for example, using an adhesive from an adhesive spraying on coating device 27, prior to applying the layer 14 of bentonite clay over the intermediate sheet material layer 13 and then overlaying the flexible cover sheet 15 over the bentonite clay layer 14, to form flexible GCL 50. One of the advantages of the GCL construction shown in Figure 6 is that when the GCL 50 is used, for example, on a sloping surface of a landfill cap, disposed such that the textile/adhered sheet of flexible polymeric sheet material layer is on the upper surface, water travelling over the upper fabric surface will not leach bentonite clay out of the GCL 50 (through the upper fabric layer) since the upper fabric layer is lined on its interior surface with a water-impermeable or low permeability polymeric sheet material layer. The polymeric sheet material layer will, therefore, prevent moving water travelling over an upper surface of the GCL from eroding or entraining the bentonite clay out of the upper surface of the article. Similarly, if moving water travels under the GCL 50 of Figure 6, the fabric/adhered polymeric sheet material layer will be disposed downwardly, so that the lower fabric has its inner surface adhered to the polymeric sheet material layer to prevent loss of bentonite clay through the outer surface of the lowermost fabric layer.

It should be understood that while Figure 6 shows the flexible carrier sheet 11 being glued to the polymeric sheet material layer 13 during manufacture, these two layers could be provided in prelaminated form prior to manufacture, to eliminate a manufacturing step. In addition to adhesively affixing the flexible intermediate polymeric sheet material layer 13 to the flexible carrier layer 11 or to the flexible cover layer 15, any other method can be used to permanently adhere the polymeric sheet material layer 13 to the inner surface of the carrier layer 11 or to the inner surface of the cover layer 15, for example, melt bonding, or spraying a polymeric melt onto the inner fabric surface.

Although only two embodiments of the present invention have been illustrated and described, it will at once be apparent to those skilled in the art that variations may be made within the spirit and scope of the invention. Accordingly, it is intended that the scope of the invention be limited solely by the scope of the hereafter appended claims and not by any specific wording in the foregoing description.

Claims

1. An improved flexible geosynthetic clay liner comprising:
   a flexible primary carrier sheet;
   a layer of bentonite clay disposed on top of the primary carrier sheet;
   a flexible intermediate layer disposed on top of the layer of bentonite clay; and
   a flexible cover sheet disposed on top of the flexible intermediate layer.

2. The geosynthetic clay liner of claim 1, wherein the intermediate layer is fabricated from a sheet of low permeability plastic.

3. The geosynthetic clay liner of claim 1, wherein the intermediate layer is fabricated from a liquid polymer spray.

4. The geosynthetic clay liner of claim 1, wherein the intermediate layer is further characterized as being a controlled permeability sheet.

5. The geosynthetic clay liner of claim 1, wherein adhesive is applied to an upper surface of the primary carrier sheet to assist in adhering the first layer of bentonite clay against the upper surface of the primary carrier sheet and adhesive is applied to a lower surface of the cover sheet to assist in adhering the flexible intermediate layer to the cover sheet.

6. The geosynthetic clay liner of claim 5, wherein adhesive is applied to the upper and lower surfaces of the intermediate layer to assist in adhering the layer of bentonite clay and the cover sheet to the intermediate layer.

7. The geosynthetic clay liner of claim 1, further including another layer of bentonite clay disposed between the intermediate layer and the cover sheet.

8. The geosynthetic clay liner of claim 1, wherein an undersurface of the primary carrier sheet has a high-friction surface to enhance frictional engagement between the lower surface of the primary carrier sheet and a sloping surface on which the liner is installed.

9. The geosynthetic clay liner of claim 1, wherein the layer of bentonite clay is contained in the clay liner in an amount of about 0.25 pounds to about 2 pounds of bentonite clay per square foot.

10. The geosynthetic clay liner of claim 7, wherein said another layer of bentonite clay is contained in the clay liner in an amount of about 0.25 pounds to about 2 pounds of bentonite clay per square foot.

11. A method of fabricating the low permeability geosynthetic clay liner of claim 1, the method comprising the following steps:

    (a) providing a flexible primary cover sheet;
    (b) depositing a layer of bentonite clay on top of the primary carrier sheet;
    (c) depositing an intermediate flexible layer on top of the layer of bentonite clay;
    (d) depositing a flexible cover sheet on top of the intermediate flexible layer;
    (e) attaching the cover sheet to the primary carrier sheet with the layer of bentonite clay and intermediate layer disposed therebetween.

12. The method of claim 11, wherein step (c) is further characterized as applying an intermediate flexible layer of polymer material on top of the layer of bentonite clay.

13. The improved flexible geosynthetic clay liner of claim 1, having a water permeability of less than 5 x 10^{-10} cm/sec, comprising:
    a flexible primary carrier fabric;
    a flexible intermediate layer secured to the primary carrier fabric;
    a layer of bentonite clay disposed on top of the intermediate layer; and
    a flexible cover fabric disposed on top of the layer of bentonite clay.

14. The improved flexible geosynthetic clay liner of claim 7, having a water permeability of less than 5 x 10^{-10} cm/sec comprising:
    a flexible primary carrier sheet;
    a first layer of bentonite clay disposed on top of the primary carrier sheet;
    a flexible intermediate layer disposed on top of the first layer of bentonite clay;
    a second layer of bentonite clay disposed on top of the intermediate layer; and
    a flexible cover sheet disposed on top of the layer of bentonite clay.

15. An improved flexible geosynthetic clay liner of claim 1 comprising:
    a flexible primary carrier sheet;
    a layer of bentonite clay disposed on top of the primary carrier sheet; and
    a fabric lined with a water-impermeable plastic sheet material disposed on top of the layer of bentonite clay, such that the plastic sheet material is in contact with the layer of bentonite clay.

16. The geosynthetic clay liner of claim 14, wherein the intermediate layer is further characterized as being a water-impermeable sheet.

17. The geosynthetic clay liner of claim 15, wherein the intermediate layer is characterized as being a water-impermeable sheet.

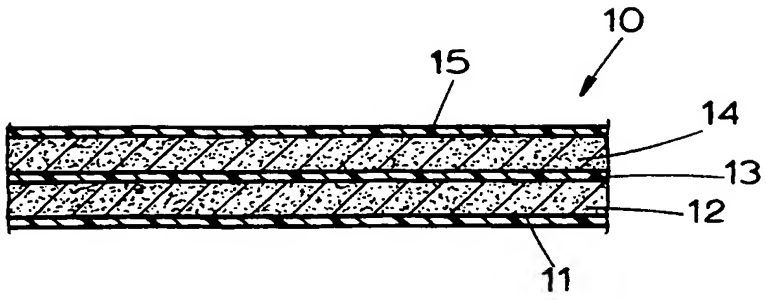


FIG. 1

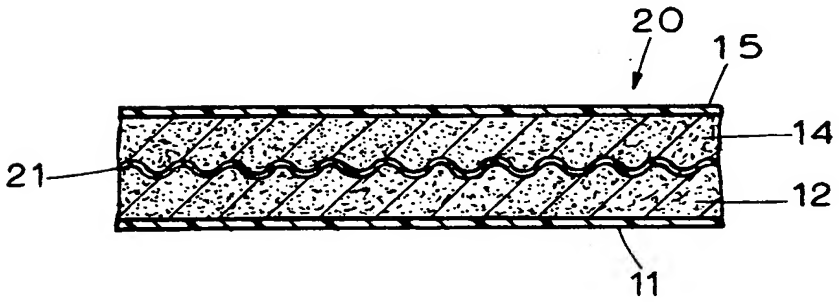


FIG. 2

FIG. 3

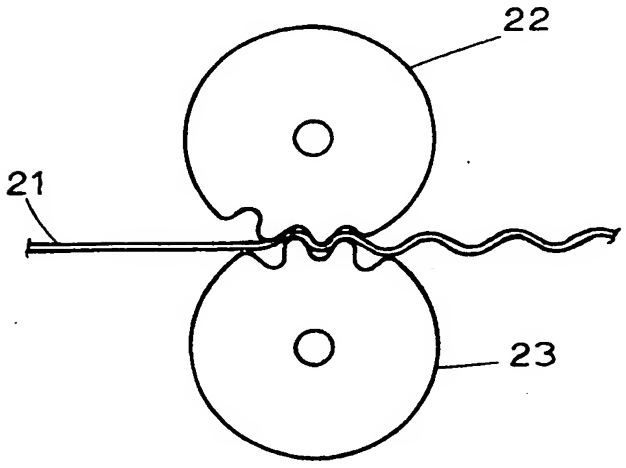


FIG. 4

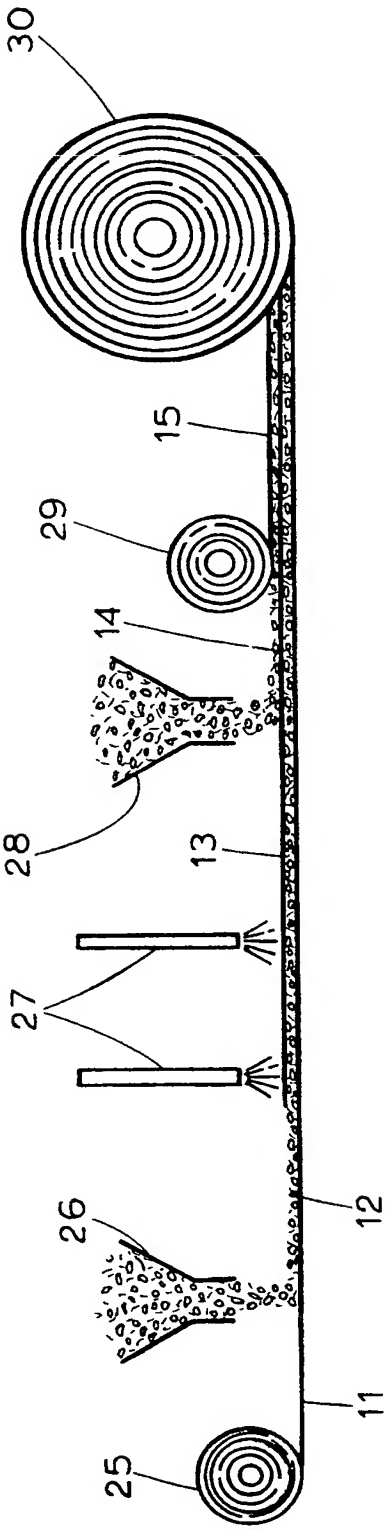
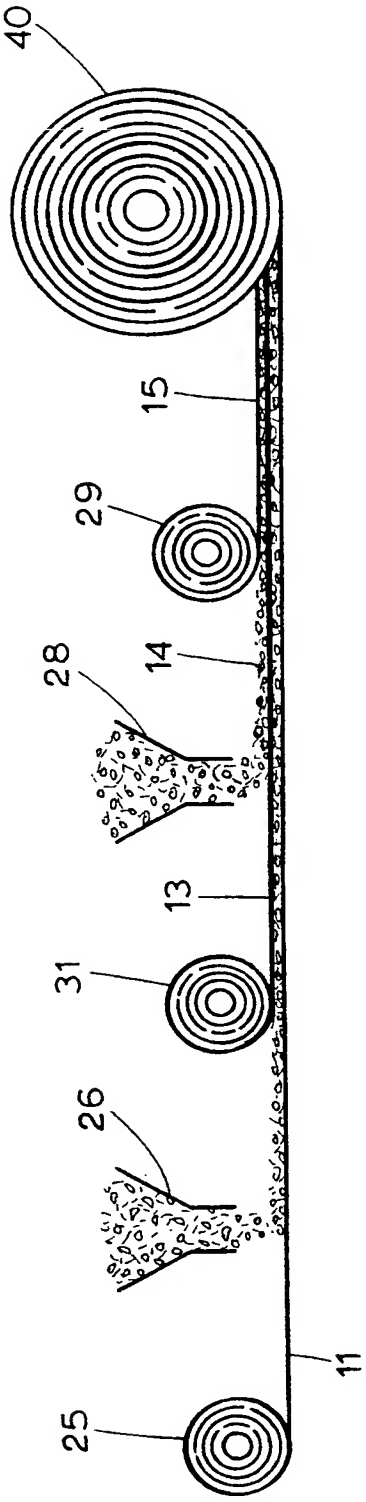


FIG. 5



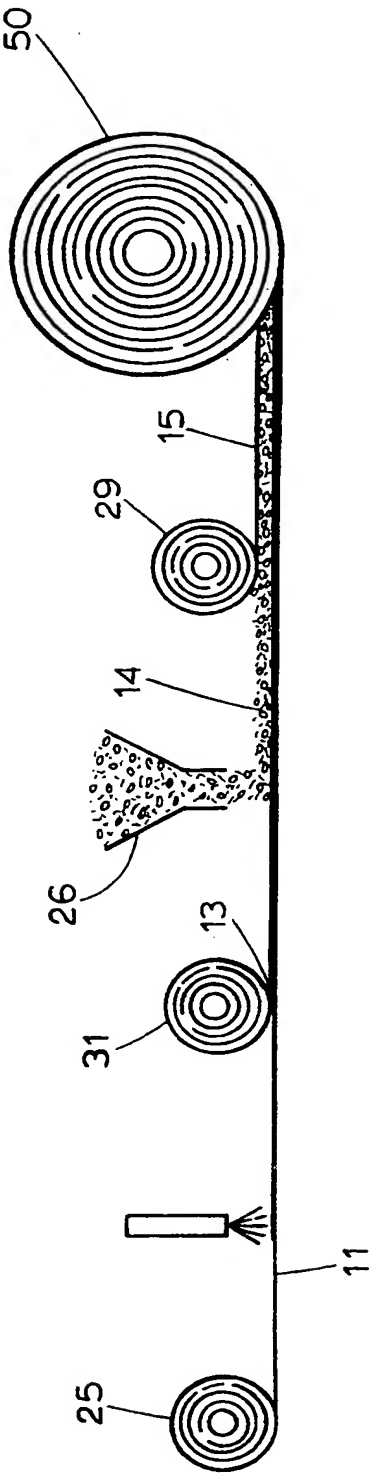


FIG. 6

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 96 10 5838

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X Y	EP-A-0 449 182 (SERVIZI ECOLOGICI SPA) 2 October 1991 * column 3, line 27 - column 5, line 53; figures 1-5 *	1,3,4 5-8,10, 13,14	E02D31/00
Y	EP-A-0 381 342 (CLEM ENVIRONMENTAL CORP) 8 August 1990 * page 2, line 24 - page 3, line 33 *	5,6,13, 14	
Y	EP-A-0 522 481 (SERVIZI ECOLOGICI SPA) 13 January 1993 * column 3, line 48 - column 5, line 27; figures 1-3 *	7,10	
X	EP-A-0 563 453 (NAUE FASERTECHNIK) 6 October 1993 * column 2, line 39 - column 7, line 11 *	11	
Y	EP-A-0 620 325 (CLEM JAMES CORP) 19 October 1994 * column 4, line 54 - column 6, line 34; figures 1-6 *	8	TECHNICAL FIELDS SEARCHED (Int.Cl.6) E02D
P,X	EP-A-0 671 510 (HOFINGER) 13 September 1995 * the whole document *	1	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	3 July 1996	Tellefsen, J

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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